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TECHNICAL REPORT STANDARD TITLE PAGE

II

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Drainage Basin Characteristics from ERTS Data 1 July 1974 - 31 Dec. 1974 (SR 342-6F)		5. Report Date 1 January 1975
7. Author(s) Este F. Hollyday (IN 389)		6. Performing Organization Code
9. Performing Organization Name and Address U.S. Geological Survey, WRD National Center 12201 Sunrise Valley Drive Reston, Virginia 22092		8. Performing Organization Report No.
12. Sponsoring Agency Name and Address Frederick Gordon, Jr. Code 902 Goddard Space Flight Center Greenbelt, Maryland 20771		10. Work Unit No.
15. Supplementary Notes (E75-10350) DRAINAGE BASIN CHARACTERISTICS FROM ERTS DATA Progress Report, 1 Jul. - 31 Dec. 1974 (Geological Survey, Reston, Va.) 10 p HC \$3.25		11. Contract or Grant No. S-70243-AG
16. Abstract Selection of techniques and equipment to isolate, extract, and measure basin characteristics seen in ERTS imagery has impeded progress. The following isolation and extraction techniques using imagery were tested: 1) Visual isolation and manual extraction, 2) isolation by equidensitometry with electronic image analysis systems and extraction by photography, and 3) isolation by equidensitometry and extraction by photomechanical means. Measurement techniques tested were: 1) Visual point count, 2) count of CRT resolution elements, and 3) integrating photometer. Due to the short period of the investigation, the scope was reduced by deleting the basin characteristics of snow and massed works of man as well as change detection in any of the characteristics. During the reporting period, ERTS-derived measurements of forest, riparian vegetation, open water, and combined agricultural and urban land use were added to an available matrix of map-derived basin characteristics. The matrix of basin characteristics was correlated with 40 streamflow characteristics by multiple regression techniques. Fifteen out of the 40 equations were improved. If the technique can be transferred to other physiographic regions in the nation, the opportunity exists for a potential annual savings in operations of about \$250,000.		13. Type of Report and Period Covered Type II Progress Rept. 1 July 74 - 31 Dec. 74
17. Key Words Suggested by Author Remote Sensing Watersheds (basins) Terrain analysis Surface runoff Regression analysis		14. Sponsoring Agency Code
18. Distribution Statement "Made available under NASA sponsorship in the interest of early and wide dissemination of Earth Resources Survey Program information and without liability for any use made thereof."		15. Supplementary Notes
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) N/A	21. No. of Pages 22. Price

Figure 2A. Technical Report Standard Title Page. This page provides the data elements required by DTD Form DF-1473, HEW Form OE-6000 (ERIC), and similar forms.

1342F

JUL 23 1975  
SIS/902.6

INT. 2097-72

DRAINAGE BASIN CHARACTERISTICS FROM ERTS DATA, 1 July 1974 - 31 Dec. 1974

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1 January 1975

Type II Progress Report for Period 1 July 1974 - 31 December 1974

Prepared for:

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Greenbelt, Maryland 20771

Publication authorized by the Director, U. S. Geological Survey

## Type II Progress Report

### ERTS-A

- a. Title: Drainage Basin Characteristics from ERTS Data, 1 July 1974-31 Dec. 1974.

ERTS-A Proposal No.: SR 342-6F

- b. GSFC ID No. of P. I.: IN 389
- c. Statement and explanation of any problems that are impeding the progress of the investigation:

This report emphasizes some of the problems encountered that will not be discussed in detail in the final report.

From "First Look" phase to the beginning of this reporting period, the principal problem impeding progress has been the selection of suitable techniques and equipment to isolate, extract, and measure basin characteristics seen in ERTS imagery. Initial accuracy requirements were dictated by the need for detecting change in the area of selected characteristics within specified watershed boundaries during the period of the investigation.

The following techniques and equipment were tested and evaluated using 1:1,000,000-scale positive film transparencies.

#### Isolation and Extraction:

##### 1. Visual isolation and manual extraction:

A clear film was placed over a single appropriate band of ERTS imagery (band 5 for forest). The distribution of a selected basin characteristic was estimated visually by subjective application of criteria of film density (which is directly related to radiance in the original scene), texture, shape, and terrain position relative to the drainage pattern. Areas believed to meet the criteria were inked-in. A separate extraction was produced for each basin characteristic. The greatest advantage of this technique over other extraction techniques is the ability to apply the very powerful criteria of texture, shape, and terrain position. The principal disadvantage is that it is difficult for the photointerpreter to apply the criteria uniformly over the scene.

2. Isolation by equidensitometry with electronic image analysis systems and extraction by photography:

The following systems were tested:

ESIAC (Electronic Satellite Image Analysis Console) at  
Atmospheric Sciences Laboratory  
Stanford Research Institute  
Menlo Park, California

MIAS (Multichannel Image Analysis System, part of  
EROS Autographic Theme Extraction System) at  
EROS Data Center  
Sioux Falls, South Dakota

GEMS (General Electric Multispectral Information  
Extraction System) at  
Space Division  
General Electric Corporation  
Valley Forge, Pennsylvania

SDS Datacolor at  
Photogrammetry Branch  
U.S. Geological Survey, T.D.  
Reston, Virginia

Image data were loaded into all four systems with a T.V. camera. The image was displayed on a CRT (cathode ray tube) where it was analyzed for ranges in film density that might be used to isolate a selected subject in the image by a technique of density slicing. ESIAC, MIAS, and GEMS are multispectral systems in that they have the capability of simultaneously slicing film densities in more than one wavelength band and of combining the results in a single isolation on the CRT. In this way any basin characteristic with a unique density or set of densities can be isolated from the other subject matter in the image. The isolated basin characteristic was photographed from the CRT to give a permanently extracted record. The greatest advantage of this extraction technique is the capability for rapid operator-equipment interaction in order to optimize the isolation based upon density slicing. An optimum isolation would identify all areas occupied by the selected basin characteristic and eliminate all other areas.



## 2. Isolation and Extraction.--Continued.

Because the photographic extraction from the CRT is marginal in geometric quality, it is difficult to obtain the required precision from subsequent measurements of area. Therefore, when the isolated basin characteristic is displayed on the CRT, it should be measured using the video planimeter that is an internal component of ESIAC, GEMS, and SDS Datacolor. When viewing an entire ERTS frame, the resolution of the CRT is only about 12 percent of the resolution of the original image. Accordingly, it is desirable to magnify a single basin and then isolate a selected basin characteristic. After measuring the area of the characteristic, another basin is selected, and the same procedure is followed. The density-slice criteria used on the first basin, however, are lost while magnifying the second basin, and a new set of criteria must be established. Under such conditions it is difficult to maintain consistent geometric and photometric criteria within a single frame. The problem is more difficult when attempting to measure change from scene-to-scene in a time sequence of the same study area.

## 3. Isolation by equidensitometry and extraction by photomechanical means:

Spot measurements were made of the film density of selected basin characteristics recorded in an ERTS image using a densitometer. These measurements together with spot measurements of the film density in the gray scale of the same image were used by the high-quality graphic-arts photographic laboratory that is part of the EROS Program Autographic Theme Extraction System. The laboratory produced binary extractions in the form of photographic transparencies using density isolation techniques. The 9-inch by 9-inch transparencies covered an entire ERTS scene at precisely the same scale. When necessary, two or more transparencies were combined or sandwiched to produce a more nearly optimum isolation of a basin characteristic. The geometry and resolution of the original image was precisely preserved and the isolation criteria were applied uniformly over an entire ERTS scene. The reliability of the final extraction may be checked visually by placing it over a 9 x 9 color composite transparency of the original ERTS imagery. The principal disadvantage lies in using a densitometer to determine the film density limits. Because it is difficult to determine any one optimum density, it is necessary to make several photomechanical extractions over a wide range in film density in order to bracket the optimum isolation of a selected basin characteristic.

## Measurement:

### 1. Visual point count:

Both a basin boundary mask and a small-increment grid were placed over the 1:1,000,000-scale extractions that were in the form of film transparencies. A basin-by-basin count was made of the grid intersections overlying areas isolated as a given basin characteristic. This number was divided by the count of the total number of intersections falling within the basin boundary. The ratio was expressed as percent of basin covered by the given basin characteristic. This measurement technique is very reliable provided several hundred intersections are counted and the investigator remains alert. The principal disadvantage is that it is more time consuming than automated techniques and more subject to human error.

### 2. Count of CRT resolution elements:

The video planimeters in ESIAC, GEMS, and SDS Datacolor can be used to count those resolution elements on the CRT screen that correspond to the isolated basin characteristic. If a basin mask is superposed on the image prior to density slicing, the planimeter will count the isolated elements within the basin only. This count was divided by the count of all elements falling within the basin boundary. This ratio was expressed as percent of basin area covered by the selected characteristic. The instant, automatic measurement at the time of isolating the characteristic is a great advantage over other techniques. The principal disadvantage is inherent in the uncertainty in setting the system gain. The video planimeter in ESIAC was used to measure areas in photomechanical extractions (rather than in the original imagery), and a 10- to 15-percent error was introduced in the final calculations primarily due to the modulation transfer function of the complex optics and electronics of this sophisticated system.

### 3. Integrating photometer:

A basin mask was prepared at a scale of 1:1,000,000 by outlining the basin boundaries on an opaque film. The areas enclosed by the boundaries were then made transparent and geographic control points were added to allow registration of the mask with imagery or photomechanical extractions of the same scale.

### 3. Integrating photometer: Continued.

Light from a photographic enlarger was focused upon an integrating photometer. The basin mask was placed between the light source and photometer. The total illumination passing through the transparent area within a basin boundary on the mask was used as a measure of the area of the basin. A photo-mechanical extraction in which the basin characteristic was transparent was then registered with the mask. The total illumination passing through both basin mask and extraction was used as a measure of the area of the basin characteristic. The ratio of illumination measurements was expressed as percent of basin covered by the selected basin characteristic.

The greatest advantage over other techniques of areal measurement is the accuracy of the measurements. Calibration of the equipment with circular holes of known diameter gave measurements of relative area within 5 percent of the calculated area. The principal disadvantage is that it is necessary to work with small scale extractions and masks because the photometer sensing element is about 50 millimeters in diameter.

- d. Discussion of the accomplishments during the reporting period and those planned for the next reporting period:

From July 1, 1973 to July 1, 1974:

1. Consideration was given to extracting basin characteristics from ERTS computer compatible tapes. Although measurement by ERTS resolution elements would be an advantage, disadvantages were foreseen in the difficulty of developing and checking optimum radiance-value criteria for isolating characteristics and in locating basin boundaries.
2. It was concluded that most automatic data analysis techniques could not yet operationally support the investigation to the tolerance levels originally conceived. A considerable amount of preliminary visual isolation and manual extraction is needed to guide and evaluate the automatic data analysis techniques. When a quick look is needed or when geometric precision is not a critical factor in the measurements, however, the isolation, extraction, and measurement operations could all be performed on ESIAC or GEMS. When greater geometric precision is necessary, the ideal system would allow isolation to be performed with an electronic image analysis system. The isolation criteria would then be used to produce a photomechanical extraction in a photographic laboratory. The geometrically precise extraction could then be measured by integrating photometer. This procedure is close to the design concept of the Autographic Theme Extraction System which was under development by the EROS Program and which was not yet operating as a system during this investigation.



From July 1, 1973 to July 1, 1974:

However, more-strictly defined or less visual basin characteristics will have to be isolated with a combination of subjective inference, manual extraction, and photomechanical extraction with increasing compromise between conceptual subject and extractible subject.

3. Snow was no longer considered a usable basin characteristic for the purpose of this investigation. Snow never covered more than one fifth of the study area. Streamflow records in rapidly urbanizing areas were either of too short a period or did not accurately portray dynamic hydrologic change for the type of regression analysis being considered. Therefore, massed works of man were also dropped from consideration. Riparian vegetation and combined agricultural and urban land use were substituted for snow and massed works. With forest and open water, they comprised the four basin characteristics that were tested in equations for streamflow characteristics. Urban land use comprises an insignificant amount of the total land use in the Delmarva Peninsula study area, and no attempt was made to isolate it from agricultural land use.
4. Detection of change was dropped from consideration. For the remaining basin characteristics it was likely that the amount of change (in percent of a basin covered) in any one during the investigation would be less than the errors currently inherent in isolating and extracting basin characteristics.
5. In a related investigation, NASA high-altitude aircraft data were used to test remotely sensed data for improving equations for estimating streamflow. Level-I land-use categories (Anderson, J. R., Hardy, E. E., and Roach, J. T., 1972, A land-use classification system for use with remote-sensor data: U.S. Geol. Survey Circular 671) were mapped using visual photointerpretation with high-altitude aircraft photography. As part of the related investigation, the area of all Level I categories within 39 gaged basins was measured and added to a pre-existing matrix of basin characteristics. Comparison of control group equations (having map-derived basin characteristics only) with experimental group equations (map-derived as well as remotely sensed land-use basin characteristics) revealed that 7 out of 40 equations could be improved significantly.

From July 1, 1974 to December 31, 1974:

The manual extractions of ERTS data were used to select the optimum photomechanical ERTS extractions available for forest, riparian vegetation, open water and combined agriculture and urban land use. The area of these four basin characteristics was measured in 20 gaged basins by integrating photometer. These area measurements were added to an available matrix of basin characteristics derived from maps and climatological data. This expanded matrix of basin characteristics was used in a multiple regression computer program to relate 43 streamflow characteristics to basin characteristics for the corresponding 20 gaged basins. Experimental equations for 40 streamflow characteristics resulted from this analysis. These experimental group equations (using ERTS-derived data) were compared with control group equations (not using ERTS-derived data). Standard errors of estimate for the two groups were compared, and a significant improvement was apparent in 15 out of 40 equations for estimating streamflow characteristics.

Activities planned for the next (final) reporting period include documenting significant procedures and submitting the final report.

- e. Discussion of significant scientific results and their relationship to practical applications or operational problems including estimates of the cost benefits of any significant results; Category 4A:

Comparison of control group equations (using characteristics obtained from maps) with experimental group equations (using characteristics from both maps and ERTS imagery) revealed 15 out of 40 equations for estimating streamflow characteristics were improved in that the standard errors of estimate were reduced by more than 10 percent. As examples, the equations for the 5-year recurrence flood peak was improved by 32 percent, the mean monthly streamflow for September by 25 percent, the 7-day, 2-year recurrence low flow by 20 percent, and the 3-day, 2-year flood volume by 60 percent.

These results improved upon previous estimates of streamflow characteristics in the Delmarva Peninsula of Maryland, Delaware, and Virginia. The technique, however, is believed to have transfer value to other physiographic regions. Currently the U.S. Geological Survey operates more than 10,000 continuous-record gaging stations nationally. It is reasonable to estimate that improved equations would allow at least 2 stations in each of 47 districts to surpass their accuracy goals and therefore be eligible for removal from the network. This could result in an annual savings of about \$250,000.

- f. A listing of published articles, and/or papers, preprints, in-house reports, abstracts of talks, that were released during the reporting period:

Articles for ERTS-1 book (Williams, R. S., Jr., and Carter, W. D., eds., 1975, ERTS-1: A new window on our planet, U.S. Geol. Survey Prof. Paper 929 (in press).

Hollyday, E. F., and Cook, J. G., 1975, Tornado tracks.

Hollyday, E. F., and Pluhowski, E. J. 1975, Improving estimates of streamflow characteristics.

Moore, G. K., and Hollyday, E. F., 1975, Discovery and significance of the Beech Grove Lineament, Tennessee.

Abstracts, American Society of Photogrammetry:

Hollyday, Este F., 1975, Improving estimates of streamflow characteristics with ERTS-1 imagery (Abs.): Amer. Society Photogrammetry Preprints to Southeastern Meeting Papers, Athens, GA.

- g. Recommendation concerning practical changes in operations, additional investigative effort, correlation of effort and/or results as related to a maximum utilization of the ERTS system.

The state of the art of automated extraction is advancing rapidly. New techniques need to be tested as to their capabilities for operational input of data on basin characteristics to the matrices used to develop better equations for estimating streamflow. Testing of the digital computer compatible tapes of ERTS was beyond the scope of this investigation.

Consideration should be given to testing basin characteristics derived from either imagery or digital tapes for improving estimates of streamflow in other physiographic areas in the nation. An economical effort might involve testing ERTS-derived land-use data available as part of other ERTS investigations.

- h,i,j. Standing Order Forms, Image Descriptor Forms, Data Request Forms:

Nothing to report.